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IS 10290 (1982): Code of practice for photogeological interpretation and mapping of river valley project site
[WRD 5: Geological Investigation and Subsurface Exploration]



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Indian Standard

CODE OF PRACTICE FOR
PHOTOGEOLOGICAL INTERPRETATION AND
MAPPING OF RIVER VALLEY PROJECT SITES

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Indian Standard

CODE OF PRACTICE FOR PHOTOGEOLOGICAL INTERPRETATION AND MAPPING OF RIVER VALLEY PROJECT SITES

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Indian Standard

CODE OF PRACTICE FOR PHOTOGEOLOGICAL INTERPRETATION AND MAPPING OF RIVER VALLEY PROJECT SITES

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 31 July 1982, after the draft finalized by the Subsurface Exploration Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 The planning, reconnaissance and construction stages of civil engineering projects offer an exceptionally wide range of possibilities for the use of aerial photo-interpretation techniques. Photo-interpretation is a simple process (Appendix A). Besides, it can be done with the help of simple tools (Appendix B) and does not necessarily require sophisticated instruments or technology. The basis of planning for such operations is to have a rapid economical and dependable preinvestment evaluation of ground conditions. Some of the factors which affect the planning of such operations are as follows:

- a) Prevailing local conditions; such as, climate, road conditions and availability of logistics.
- b) Type of the project which governs the scale of aerial photographs for reconnaissance and detailed survey and also the extent of area to be covered.
- c) Geological conditions of the area.
- d) Availability of trained staff. This is a very important criteria, as the quality and accuracy of interpretation depends on the experience and capability of the staff available. He should not merely be a trained interpreter but also a good geologist to prepare a reliable map and submit a report highlighting the geological features, which may be of importance for such projects.

0.3 Interpretation is a natural science and the best interpreter has to be an integrated earth scientist who uses photography to advance his special interest without losing sight of the numerous affecting and affected terrain components that also enter the picture.

0.4 For the purpose of this Code the following problems have been taken into consideration for standardizing the methods of photo-interpretation mapping:

- a) Regional tectonics and related seismicity;
 - b) Reservoir, damsite, and catchment mapping and planning for collection of hydrometeorological data and silt control;
 - c) Tunnel alignments;
 - d) Power station sites; and
 - e) Canal alignment and command area studies.
-

1. SCOPE

1.1 This standard covers the method for the photogeological mapping and interpretation of river valley project sites.

2. TYPE OF AERIAL PHOTOGRAPHS

2.1 Photographs differ in angle and the scale at which they are taken. Photographs bear letter and number identifications on the corners, denoting the letter or number of strip, roll or project, the number of the exposure and the date the picture was taken. They bear collimation or fiducial marks rigidly connected with the camera or sides or corners of the negative to locate the centre or principal point of the photos. Other pieces of information available on the photograph include the agency taking the photographs, the date, the location in latitude and longitude, focal length of the lens and approximate height of the flight to compute the approximate scale.

2.1.1 Aerial photographs taken with vertical camera axis from heights ranging from 2 000 to 6 000 m are vertical photographs. The term is approximate as no aerial photograph is really vertical in geometric sense. It has a tilt caused by the slight deviation of the plane from the horizontal. Aerial photographs also have crab or drift caused by the straying of the plane due to strong side winds from its scheduled line of flight. The tilt causes unusual distortion of images and the crab sometimes leaves gaps in strips. Since best geometric accuracy is obtained in near vertical photographs, no aerial photographs which have a tilt higher than 3° should be used for interpretation purposes, and no crab should be permitted in flight lines.

2.1.2 The rectified multi-lens composite photos, made for preparation of topographic maps are not suitable for evaluating ground conditions as they have poor stereoscopy.

2.1.3 Characteristics of some of the different types of aerial photographs available in the country and used in interpretation are given in Appendix C.

2.2 Photograph Index and Mosaics

2.2.1 Photographs are loosely taken frames of a terrain and should be properly indexed to fix the position of exposure. This is done with index sheets which are graphic or photographic assemblages of a photo-coverage of an area fixing the approximate position of a photo in a terrain. Index sheets contain run and exposure number of the photograph taken with geographic markings of the position. Photo-index sheets, if correctly assembled, may sometimes serve as a crude reconnaissance map-base.

2.2.2 Photo-interpreters rely widely on mosaics which are planimetric maps, composed from aerial photographs. A mosaic is a continuous assembly of vertical photos pasted on a composite aerial photographic map sheet using the cut-out centre parts of the photographs. A mosaic is uncontrolled when assembled only with the aid of a continuous feature like a stream, a shoreline, a road, etc. It is controlled when the uncontrolled assembled mosaic is sectionally rephotographed with the scale adjusted to ground controlled points.

2.3 Stripping, Overlap and Photo Format — Vertical aerial photographs are taken in continuous rows, called runs or flight strips. Normally photographs are taken in longitudinal strips. The consecutive photographs overlap each other by about 60 percent on line of flight, called forward overlap, and above 30 percent on parallel side runs, called the lateral/side overlap.

2.3.1 When the area to be photographed is very narrow compared to its length, longitudinal stripping is not desirable. In sedimentary succession, especially with high dip-angles, the distortion of dip is very strong and may be completely reversed near the edges of the photo running parallel to the flight line. In such cases, cross-stripping, that is, flight lines at right angles to the strike of the structure, becomes necessary. This considerably reduces the distortion in view of the larger overlap (60 percent) over the full width of the model across the line of flight. But such cross-stripping may only be economical if the length of the block is less than three times its width. If it is longer and narrow, much dead flying increases the costs. The numerous turns cause the pilot to lose his bearings for regular overlap. They may give rise to increasing incidence of variation in scales. In such a case longitudinal stripping should be resorted to with correspondingly

large lateral overlap varying from 45 to 60 percent depending upon the structural conditions (45 percent for low dips; 50 percent for moderate and 60 percent for high dips or a combination of these, if the structure is strongly asymmetric).

2.3.2 The photographs have a square format and normally come in sizes of 18×18 cm and 23×23 cm. The size of the print is of not much importance so far as interpretation is concerned but it affects cost and time of mapping. Large size prints cover a larger area with less printing, simplify plotting, computing and point transfer work. Hence 23×23 cm size photos are preferable to the smaller formats. The area covered on this format on different scales and at different lateral overlaps is given in Appendix D.

2.4 Scale of Aerial Photographs — The scale of an aerial photograph is obtained by the formula f/H where ' f ' is the focal length of the lens and H the height of the flight. As the topographic undulations introduce variations in H , most photographs have only approximate scales which are true for only one datum place. The practical approximate scale ranges from 1 : 5 000 to 1 : 60 000, the most frequent being 1 : 20 000, 1 : 30 000 and 1 : 40 000. Large scale photos give more details, have less coverage per photo and are more expensive. Smaller scales bear less details, have larger coverage, show continuity of features and are more economical and take less time to evaluate. In large scale projects lands at imagery may be utilized for preliminary planning. Recommended scales of aerial photographs for various studies are given in Appendices E and F.

2.5 Annotation of Photographs — The aerial photographs have fiducial marks collimating on their four sides. Connecting the markings, a cross may be constructed with a cross point on the centre of the photo. This is the centre or principal point of the photographs. It is of importance in the assemblage of the single photograph into a group tracing strip or mosaic. The centre is usually marked with a needle and surrounded by a coloured circle, or the principal point is indicated by a cross.

2.6 Resolution of the Photograph

2.6.1 The clarity of resolution is never too good for an interpreter. All photographs should be taken only in full sun-shine and preferably in dry season to avoid cloud cover and excess of foliage. Clouds should never exceed 10 percent of the coverage. In India, the period from October to March is best suited for taking serial photographs.

2.6.2 Photographic defects like weak or negative with too much contrast are being electronically corrected now. The paper preferred is double weight semi-matte paper to prevent warping and glare. It may also be easily annotated with ordinary glass marking pencils.

3. MAPPING TECHNIQUES

3.1 Basic Requirements — The three basic requirements for preparation of an interpreted photo-geological map are as follows:

- a) The aerial photographs,
- b) The stereoscope, and
- c) The topographic base maps.

The photo-interpreted map shall be analysed and field checked.

3.1.1 There are two types of maps used to construct photo-geological maps. The first is the planimetric map which gives only horizontal information. Photo-interpretation is mostly aimed at obtaining a planimetric map showing the position of rock types, soil or structural features. The second type is topographic map showing, in addition to the details of planimetric map, contours as well. Contours are essential in engineering projects to obtain detailed data on geological structure.

3.2 Some Aspects of Photogrammetry

3.2.1 An aerial photograph is a perspective picture and does not depict the topography in its true shape or scale. It provides a distorted picture of the land, the amount and nature of distortion depending upon the geometric position of the camera lens-plate combination at the instant of exposure, factors inherent in the aerial photographic method and the nature of terrain being photographed. Therefore, this photo evaluated map contains planimetric inaccuracies due to variation of scales and displacement of images.

3.2.2 The distortion related to the geometric position of the lens-plate combination is called distortion due to tilt in the X and Y directions. Recently much advance has been made in the reduction of tilt, but it has not been completely eliminated. However, there are techniques of eliminating or compensating for its effects by rectification of the photograph.

3.2.3 The distortions due to factors inherent in the aerial photographic methods are related to: (a) instability in the dimensions of film and photographic paper (b) optical properties of the camera lens and (c) the inevitable radial distortion involved in a perspective view. The first two causes have been greatly minimized by research, the third cannot be reduced, but it is an aid in obtaining the stereo-vision.

3.2.4 The distortions due to the nature of the terrain are related to the variations in the flying height caused by uneven terrain, together with the additional effects that such uneven terrain has upon radial distortion.

3.3 Controlled Planimetric Maps

3.3.1 Controlled planimetric base maps may be prepared by radial triangulation without any ground control, which have a consistent scale.

3.3.2 The topographical, geological and other details, such as land form, land use, etc, may be filled in by tracing on a transparent material placed over the photograph after local adjustment for scale between 'details points'. If high accuracy is not required, a single-line cross-section may be plotted by the use of a simple parallex-bar, using the river surface at the site as the local datum. If control points can be located in the area and identified upon the photograph, a dependable topography can be plotted and a more accurate cross-section prepared.

3.3.3 Topographical maps may be prepared from aerial photographs by establishing ground control followed by good photogrammetric mapping. *Inter-alia* these are useful for determination of the storage or volume versus area relationship.

4. GEOLOGICAL INFORMATION

4.1 Photo-interpretation maps are of wide variety reflecting the purposes for which they are constructed. The photo-geological mapping should contain such tectonic interpretations as anticlines, synclines, faults, and boundaries of outcrop types. It is also necessary to separate landforms where bedrock outcrops cannot be expected from areas where field observations will obtain results. Alluvial, talus, landslides, glacial deposits, terraces, dunes and loess should be indicated separately from bedrocks. Terraces and terrace scraps often show the underlying bedrock along the slopes and should also be marked according to their sequence. The bedrock map is initially a geological map and secondly morphological, denoting different types of landforms or drainage. In maps prepared for engineering projects, though bedrock plays an important part, the surfacial and unconsolidated materials have also an important role in planning borrow pits for construction materials. The following details should, therefore, be delineated on such maps:

- a) Location, origin and texture of various unconsolidated deposits and soils;
- b) Origin, type and structural characteristics of bedrock. This should include the following:
 - 1) Lithologic units, groups or complexes which can be identified, classified and outlined on photographs;
 - 2) Indication of the dips and strikes;

- 3) Continuity of beds, layers, complexes, fold patterns and plunges;
 - 4) All indications of faulting regardless of throw or character; and
 - 5) Unconformities, disconformities, truncations or interruption of features followed on the photographs;
- e) Location of sand, gravel, clay, boulder fields and organic deposits;
 - d) Delineation of well-drained, imperfectly drained and water-logged areas;
 - e) Location of areas of shallow or variable overburden;
 - f) Location of side hill seepage and potential landslide zones;
 - g) Nature of vegetation;
 - h) Nature of surficial drainage and erosion net;
 - j) Nature of land-use complex;
 - k) Nature of the environmental relationship between any or all terrain factors;
 - m) Points of orientation, for example roads, towns and units to facilitate field-control and identification of objects;
 - n) Rehabilitation measures involved/suggesting alternative sites;
 - p) Slope materials and their stability in the changed environment (after reservoir is filled up). This should be given a very careful consideration as the life of most of our projects has been drastically cut down due to large amount of silt being derived from reservoir slope due to slumping under changed water regimen; and
 - q) Demarcation of excessive silt contributing areas.

4.2 Operations Flow Chart — Summarizing the methodology of the preparation of photo-interpretation maps, the following operations flow chart *see* Fig. 1 is suggested (*see also* Appendix G).

5. SEISMICITY PROBLEMS

5.0 Engineering problems related to earthquakes can be broadly classified into two categories:

- a) To establish what the nature of the risk would be if the planned structure is built in the given region, and
- b) To establish a certain basis of structural design in seismic regions. These are based on certain theoretical studies and actual motion and damage during an earthquake.

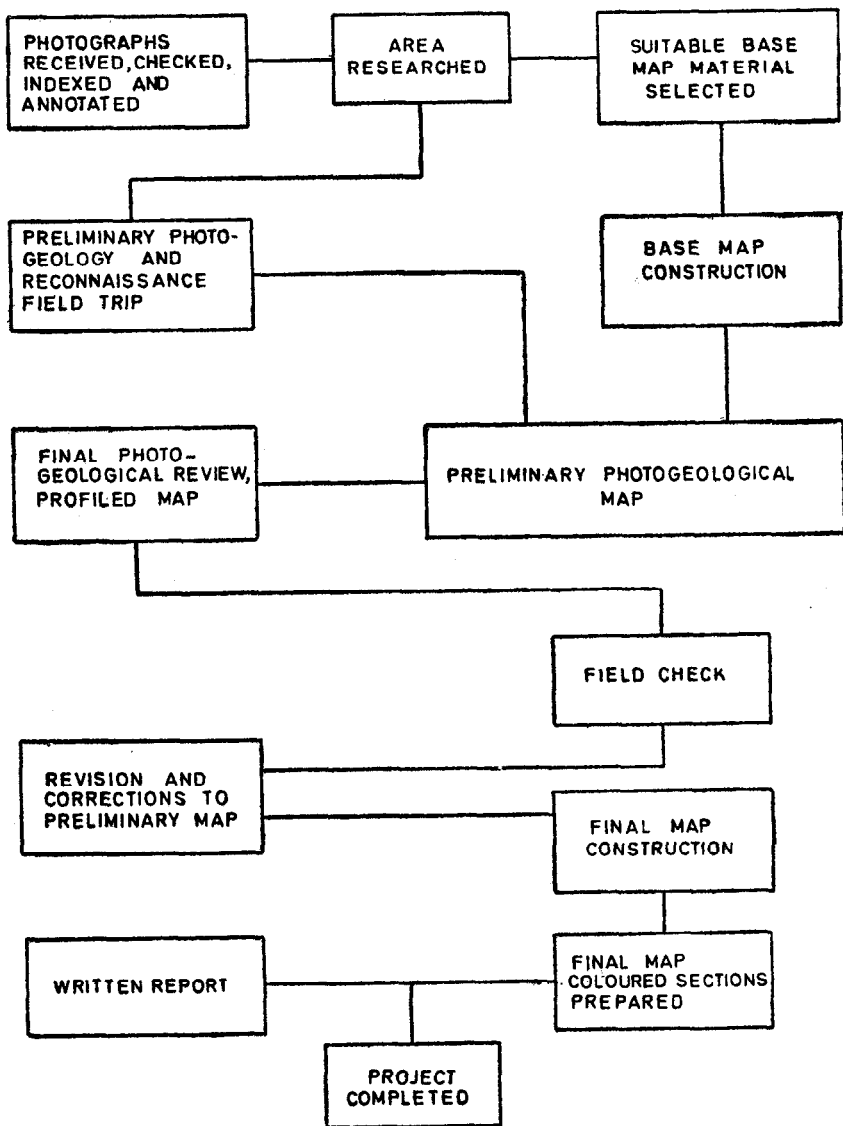


FIG. 1 OPERATIONS FLOW CHART

5.0.1 Aerial photo-interpretation techniques may be used to obtain the following information:

- a) Determining the suitability of location, and
- b) Study of the earthquake effects.

5.1 Determining the Suitability of Location — Based on observations it has been found that damage to a structure is maximum under the following two conditions:

- a) When a structure has been sited astride or too close to a tectonic feature, which has been activated during the earthquake; and
- b) When the structure is founded on deep alluvial deposits or other unconsolidated materials. Structures located in such area suffer more severe shaking than similar structures founded on bedrock.

5.1.1 When a location of a structure is planned in any area, aerial photographs of the area shall be studied and the following determinations done:

- a) Is there a major or minor tectonic feature present in the area? Since these features can be picked up better on aerial photos than on ground investigations, this study is very helpful;
- b) Whether any record exists to show that this feature has been re-activated in the past. If earlier photographs or geological maps of the area are available, a comparative study may show, whether the feature has been active in the recent or distant past; and
- c) A detailed geomorphological map of the area prepared from aerial photographs may show the following features which may be of use in the consideration of desirability of locating the planned structure in the area:
 - 1) Nature of the terrain, whether rock outcrop is available or the area is underlain by unconsolidated material;
 - 2) Nature of rock present in the area or, if unconsolidated material is present, approximate idea of the thickness and nature of the alluvial fill;
 - 3) Existing landslides in the area or potential landslides which may cause destruction, if the area receives an earthquake shock; and
 - 4) Recent faults and recent activity on older faults.

5.2 Study of the Earthquake Effects — The earthquake intensity scale depends on the perceptibility and destructivity of an earthquake. To gather exact data on these points, instrumental records of earthquake vibrations are supplemented by information gathered from individuals through various types of questionnaires. Though the degree of damage may be estimated correctly and objectively by field parties, the answers to questionnaires normally suffer from personal equations. In addition, if the earthquake occurs in some uninhabited or sparsely inhabited areas, considerable time gap may lapse before this information can be obtained. There is also the possibility that some phenomenon associated with alluvial areas, such as temporary springs or sand boils, may not come to light at all. On the other hand, if the area is aerially photographed immediately after an earthquake, a permanent record is gathered of the affected area which can be analysed in the laboratory with photo-interpretation techniques; thus exact information on the damage and the associated phenomena caused by an earthquake may be obtained.

6. MAPPING OF DAM AND POWER HOUSE SITES AND RESERVOIR AREAS

6.1 From the engineering geology point of view, the following information is required for a dam site: local supply of construction material, geology of dam and structure foundations; areas of potential landslide and seepage; characteristics of the reservoir; and the siting of appurtenant structures. The steps mentioned under **6.2** to **6.4** are suggested for this purpose.

6.2 Reconnaissance Survey — The first step in a dam and reservoir project is the identification of the topographic possibilities in the basin that seem to offer a reasonable chance of satisfying the proposed scheme. The topographic maps prepared from aerial survey are a useful aid for this stage of survey.

6.3 Preliminary Investigations — The following information should be gathered:

- a) Topographic plans and sections for location of structures including access, location of construction camps and construction plants, location and layout of rehabilitation areas;
- b) Geological and soil maps-regional and detailed for component features;
- c) Maps showing likely sources of different construction materials (quarried rocks, quarrying site for sand and gravel, earth materials; borrow areas);

- d) Topographical contour maps for studies of reservoir area, such as submergence of townships, mineral deposits and archeological sites; and
- e) Delineation of areas of potential landslides and leakage of stored water.

6.4 Detailed Investigations

6.4.1 Dam Sites — The preliminary studies bring to light defects disqualifying some of the sites. The broadly acceptable sites should be studied in detail to assess their suitability.

6.4.1.1 Area to be covered — The proposed dam site and the vicinity in a radius of one kilometre shall be covered.

6.4.1.2 Information required — The following information should be gathered:

- a) Characteristics of the valley:
 - 1) Origin of the valley and probable nature of sedimentation.
 - 2) Width of the valley and area of flood plain.
 - 3) Presence of rock outcrops; type of rock; visible lines of weakness or rock defects.
 - 4) Details of access to the proposed site.
- b) Location and extent of landslides:
 - 1) Ancient landslides along abutments.
 - 2) Recent landslides along abutments.
 - 3) Potential zones of landslides along abutments.
- c) Geological and topographical factors affecting the location and design of the following ancillary structures:
 - 1) Spillway.
 - 2) Tunnels or conduits and power houses.
 - 3) Diversion works.
 - 4) Inlet and outlet structures.
 - 5) Project township location.
 - 6) Highways and railways.

6.4.2 Reservoir Area

6.4.2.1 Area to be covered — Impounded area of the reservoir and the site of the proposed ancillary structures shall be covered. However, if the preliminary studies indicate the possibility of leakage from the reservoir area to the next drainage basin, that basin should also be mapped.

6.4.2.2 Information required — The following information should be gathered:

- a) Area of agricultural land and number of buildings which will be flooded, for which compensation has to be paid;
- b) Effect of flooding on transportation routes;
- c) Approximate storage capacity of the reservoir;
- d) Location and arrangement of pervious and impervious materials, particularly near the dam;
- e) Likelihood of leakage at the rim of the reservoir; and
- f) Probable rate of silting and the method of water-shed management.

6.4.3 Catchment Area Mapping, Silt Control and Collection of Hydro-Metrological Data — Study of catchment area of a proposed dam is necessary as a hydro-logic and silt control network may be required to be established or strengthened for obtaining information on stream flows and their pattern including sediment data. It may also be necessary to evaluate catchment characteristics for obtaining relationships of the rainfall/run-off ratio for the catchment. Mapping of the catchment area may also be required for having an idea of the regional geology for assessing prospects of leakage into adjacent catchment.

6.4.3.1 Area to be covered — The catchment area of the basin under consideration with some overlap of the adjoining basins shall be covered.

6.4.3.2 Information required — The following information should be gathered:

- a) Area of catchment, shape, topography, drainage pattern, land forms culture, land use, existing storage and diversions to evaluate catchment characteristics for establishment of rain-fall run-off relationships;
- b) Topography, geology and geomorphology of the area to ascertain the possibility of valley storages, detention basins and underground storages and to determine infiltration rates into the soil;
- c) Geological features, land-forms and vegetation cover: (1) to evaluate the erodibility characteristics of different substrates and to indicate the possible hazards of landslides, and (2) to delineate the potential areas of leakage into the ground or to the adjacent catchment basin; and
- d) Soil conditions prior to precipitation.

6.5 Power House — The information required to be gathered for power house site is similar to that for dam site. For this purpose steps suggested for dams under **6.2** to **6.4** are recommended. It additionally involves study of photographs for slope stability and recognition of joint pattern in rock mass.

7. TUNNEL ALIGNMENTS

7.1 All tunnel projects need careful planning to avoid difficult geological conditions and hazards. Photo-geological interpretation has become a very essential and useful tool for obtaining such information quickly.

7.2 Reconnaissance Survey — Several sites are considered for geological investigation and for the comparative study of design and cost of structures. Information is needed on the relative difficulty and cost of tunnel excavation in various rock formations, need of timber or other roof support, water-bearing capacity of the rocks penetrated, likelihood of encountering faults or other zones of weakness, etc.

7.3 Detailed Investigation — Having selected a site after reconnaissance survey, the area is further studied to find out where detailed surface and subsurface explorations should be carried out. The basic requirement is preparation of a geological map showing various formations, structural features, such as faults, joints, dips and strike of the various beds, contacts between formations and any unusual water occurrence, such as seepages or hot springs. Based on the geological map, a geological profile along the centre line of tunnel should be drawn. The profile should show the different types of rocks and soils along the tunnel line, geological contacts and faults or fracture zones.

7.3.1 Area to be Covered — Critical features should be mapped for one kilometre on either side of the chosen alignment.

7.3.2 Information Required — The following information should be gathered:

- a) Comprehensive study of the topography along the tunnel alignment. Measurements of slopes should be carried out to find out whether suitable rock cover is available;
- b) Drainage pattern and its origin;
- c) Character of rock along the projected tunnel at the proposed depth — whether the alignment passes through one rock unit or a number of rock formations are present;
- d) Presence of springs along the proposed alignment;

- e) Old land-slide zones and areas susceptible to landslides;
- f) Effects of tunnel excavation on nearby buildings and structures; and
- g) Possibility of the tunnel causing interference with the surface or subsurface water regime in the ground over the tunnel.

8. CANAL CONSTRUCTION AND COMMAND AREA STUDIES

8.1 In location of canals information is needed on topography, soil, rock, drainage and erosion conditions. Problems in canal construction involve soil mechanics, excavations in cuts, landslides generated by excavations and occasional heaving or subsidence of floors. Photogeological analysis provides a means of quick mapping for such surveys.

8.2 Preliminary Surveys — This involves preparation of regional geological and geomorphological maps for evaluating terrain conditions, river crossings, stability of slopes in rock cuts and the nature of the soil.

8.3 Detailed Surveys — In the construction of canals, geomorphology plays a greater role than bedrock geology, unless the canal lies in a hilly terrain. Problems in canal construction involve preparation of large scale geological, geomorphological and soil maps. This is best carried out on large scale aerial photographs.

8.3.1 Area to be Covered — Soil and topographical conditions over an area of one kilometre on either side of the proposed alignment should be studied in detail.

8.3.2 Information Required — The following information should be gathered:

- a) Topography of the area, whether level or undulating and whether any deep cutting will be required;
- b) Sharp changes in slope;
- c) Any major river-crossings involved;
- d) Whether any swamp or wet areas have to be crossed;
- e) Nature of the bed rock or nature and depth of the alluvial material. These should be examined from the following points of view:
 - 1) If rock outcrop is present, character of the rock and nature of excavation involved;

- 2) Stability of slopes in rock cuts. If alluvial material is present, character of the material with regards to its excavation properties and stability of slopes in solid cuts;
 - 3) Possibility of seepage loss and sections where the canal should be lined;
 - 4) Presence of any mineral in the soil which may have a deleterious effect on the canal water;
- f) Possibility of silt deposition in canals as a result of decrease in longitudinal grade of the canal;
- g) Possibility of erosion of its banks or along the bed of the canal due to increase in the transporting capacity of the canal in passing from one reach to another. This may be due to an increase in the longitudinal grade or narrowing of the cross-section; and
- h) Likely effect of the canal on the ground water regimes of the area.

8.3.3 Scale of the Aerial Photograph — Since terrain evaluation studies for canal construction need determining of micro-relief features and preparation of detailed soil maps of the area, photographic scale of 1 : 15 000 should be adopted for this purpose.

8.3.4 Command Area — The coverage of the command area is required for identification of culturable and cultivated areas, or for land configuration and drainage pattern and for soil and land classification for use in planning. Reconnaissance soil surveys are undertaken to provide quick and preliminary assessment of the command area. During post-irrigation investigation, for easy detection and demarcation of waterlogged areas, infra-red sensitive film would be more useful. Other informations required to be gathered is on waterlogging in the area, soil erosion and shoot erosion. Since these involve soil mechanics, it should be carried out by a soil scientist trained in photo-interpretation.

APPENDIX A

(Clause 0.2)

PROCESS OF AIR PHOTO-INTERPRETATION

A-1. PRINCIPLE

A-1.1 The general principles of air photo-interpretation is the identification and mapping of recognition elements.

A-2. PHOTOGRAPHIC ELEMENTS

A-2.0 Following are the photographic elements:

- | | |
|--------------|------------------|
| a) Tone, | b) Texture, |
| c) Pattern, | d) Shape, |
| e) Size, and | f) Relationship. |

A-2.1 Tone — It designates the amount of light reflected by the objects and consists of recognition of the following different grey tones:

- | | |
|-----------------|--|
| a) Dark tone | Rough surface, wet impervious soil or high ground water, or dense vegetation |
| b) Light tone | Smooth surface, arid conditions, snow or ice |
| c) Mottled tone | Lithological or porosity changes |
| d) Banded tone | Interbedded rocks of different colouration. |

A-2.2 Texture — Texture of a photographic image is the frequency of tone change within the image, produced by an aggregate of unit features too small to be clearly discernible individually on the photograph. It is a function of photographic scale. Textures are classified as under:

- | | |
|-----------------|------------|
| a) Fine, | b) Coarse, |
| c) Mottled, and | d) Blocky. |

A-2.3 Pattern — It is an important recognition element. It represents orderly or the typical spatial arrangement of geological, topographic and vegetation features, on the photograph which may lead to their identification. Patterns may be man-made or natural.

A-2.4 Shape — The shape of an object, such as a building, a volcano, a dike, etc., may readily identify the object. Man-made shapes are easily identified but natural forms are difficult to recognise. Examples of features recognizable by shape are sand dunes, river terraces, alluvial fans, strike ridges, etc.

A-2.5 Size — The size of an object may sometimes be identified by relating it to known objects on the photograph or by studying the shadows cast by the object.

A-2.6 Relationship — The relationship of the object to other objects on the photograph may assist in identification, for example, dams, other cultural or natural objects, ridge man-made or natural, etc. Kettle-holes represent glacial terrains, linear features — faults, dykes, etc.

A-3. GEOTECHNICAL ANALYSIS

A-3.0 After the preliminary examination, the photographs may be analysed from geotechnical point of view to study the following features:

- a) Landforms,
- b) Vegetation cover,
- c) Drainage patterns and density,
- d) Erosion patterns, and
- e) Land use.

A-3.1 Landforms — They permit the identification of soils and their parent material, sink-holes and karst topography suggest presence of limestone, dip-slopes indicate sedimentary rocks. Presence of terraces, beaches, moraines, etc, all help in obtaining information from the photographs. These are specially useful in covered or forested areas. The slope-gradient in the vicinity of streams, where slopes tend to be higher and eroded by accumulated run-off may indicate the soil material. Sand and gravel have steeper slopes than clayey soils. When river terraces are examined as source of gravel and sand material, the sections with rolling and flat slopes ordinarily should be excluded from consideration.

A-3.2 Vegetation Cover — The type of vegetation as well as its density are indicative of moisture content of the underlying soils. Certain types of vegetation, such as willows (known as indicator plants), are known to grow only where moisture content is high. Sago and Mosquito are known to grow only where moisture content is low. The plants can usually be identified by their pattern, colour and relationship.

A-3.3 Drainage Patterns and Density — These are very important elements of aerial photo-interpretation.

A-3.3.1 Drainage Patterns — These are characteristic of a given soil or rock type or of a complex of several materials. A change of soil or rock type, generally, is accompanied by a change of drainage pattern. There are six basic drainage patterns:

- a) *Dendritic (arborescent or tree-like)* — It commonly develops over horizontal, homogeneous rocks and exhibits uniformity in all

directions. Its development is dependent on the rock type, for instance, it is much simpler on granite than on shale. Limestone country has sink-holes.

- b) *Trellis pattern (grapevine pattern)* — It develops usually in folded or dipping rocks with a series of parallel faults. The primary tributaries of the main stream are long and straight and often parallel to each other and to the main stream. Secondary tributaries are short and stubby and join the primary tributaries approximately at right angles.
- c) *Radial drainage* — It consists of streams flowing radially either from a centre (volcanoe, dome) or towards a centre (basin).
- d) *Parallel drainage (Cauda Equina or Horse's Tail)* — The streams are nearly parallel to each other. Such patterns develop on more or less uniform, rather loose deposits, for example, valley fill, pronounced slope, etc.
- e) *Annular drainage* — The main streams are radial and the tributaries roughly annular, for example, running around a dome or plunging folds.
- f) *Rectangular drainage* — The tributaries join the main stream or primary tributaries at nearly right angles. It is characteristic of faulted or jointed rock-units.

A-3.3.2 Drainage Density — If the tributaries are closely spaced (high density), local soils and bed rocks have poor resistance to erosion (clay, shales, silts or sandy clays). If the tributaries are widely spaced (low density) the bedrock or soil mantle is resistant to erosion and consists of sandstones or other resistant rock, granular deposit, unconsolidated glacial till, etc. Rugged relief with high precipitation would tend to give close spacing to the tributaries, even though they may be flowing over very resistant strata. A very low relief, combined with an arid climate (low precipitation) would result in wide spacing of tributaries even though the soil or bed rock may have low resistance. Generally speaking, similar terrain conditions are shown by similar patterns and density in the same region.

A-3.4 Erosion Patterns — These are also of considerable help in photo-interpretation. Of these, gully erosion is important. The cross-section of gullies is not the same in different soils.

The gullies in granular (sandy) soils are short and steep and of a triangular cross-section.



Gradient short and steep

In silts and loess, the gullies are rectangular with compound gradients first steep and later flat.



Compound gradient

In clay, the gullies are long and flat with flat, curved cross-sections.



Gradient long and flat

A-3.4.1 Gully formation is again subject to general topography and the amount of precipitation and deviations from the above may be found. Except for gully development, no systematic drainage develops on sand surfaces, kames, eskers and limestone regions, due to a high degree of permeability and development of subsurface drainage, of course not considering a desert type climate.

A-3.5 Land Use — It gives the information of the soil conditions of the area. Rugged topography and associated sandy soils developed on sandstones are generally left in forest. Comparatively level topography and associated clayey soils developed on shales and limestones are cultivated. In flood plain areas of river basins, the silty sands of natural levees is cultivated because of its topographic condition above the lower backswamps. It is also known that orchards thrive in well drained locations (gneissic north slopes of Himalayas) and imply good sub-drainage. Shallow drainage ditches in areas of little relief commonly signify plastic, poorly drained soils.

A-4. CONVERGENCE OF EVIDENCE

A-4.1 Usefulness of recognition elements is enhanced where they may be used in combination, as mutually supporting recognition elements. An association of photographic tone, topographic expression and texture may permit interpretation of bedding even in areas of sparse outcrops.

APPENDIX B

(Clause 0.2)

EQUIPMENT NEEDED FOR CARRYING OUT AIR-PHOTO-INTERPRETATION

B-1. EQUIPMENT

The following equipment is required:

B-1.1 Aerial photographs of the required scale.

B-1.2 Stereoscopes — The function of a stereoscope is to deflect normally converging lines-of-sight so that each eye views a different photographic image thus producing a stereo-model. There are basically two types of stereoscopes:

- a) **Lens Stereoscope:** Commonly known pocket stereoscope, it has plano-convex lenses, with upper side flat, and a focal length of 100 mm. Since the normal viewing distance is 250 mm, it gives a magnification of 2.5. This also has a changeable eye-base. It is cheap and handy and useful in field, but normal size photographs (23 × 23 cm) have to be folded for viewing.
- b) **Mirror Stereoscope:** They are very useful for laboratory work, as they provide best working condition. Normally the distance between corresponding points is kept at 240 mm, thus increasing the eye base. They have an effective magnification of 0.8 x. To magnify the image additional oculars are provided to give a magnification of about 1.8 x.

B-1.3 Parallax Bar — To compute difference of heights between terrain points, a simple instrument called parallax bar is used and the height difference calculated with the help of approximate parallax formula:

$$h = \frac{Z}{b} \cdot \Delta p$$

where

h = difference of heights between the terrain points,

Z = average flying height above the main terrain,

b = photo base in mm,

Δp = parallax difference in mm between the terrain points, and measured with the help of a parallax bar.

B-1.4 Sketchmaster — The simplest way to get a rectified image of a photograph with tilt is by sketchmaster. The rectification is done optically. These are also used for transferring data from vertical or near vertical photographs to map by tracing. Commonly Zeiss Aero-sketchmaster or stereo-sketchmaster are used.

B-1.5 Radial Line Plotter — It is also a simple instrument for planimetric mapping and is based on radial line method which makes use of the principle that in photograph with small tilts, the nadir point and principal point are nearly coincident, so that relief displacement is considered radially from the principal point.

B-1.6 Optical Pantograph — It is used by photo interpreters to transfer details from photographs to a map or manuscript sheet of different scale.

B-1.7 Slotted Template Cutter — Preparation of a controlled planimetric map is done with the help of some ground control points either by Aerial Triangulation in space or by Radial Triangulation. With only a few ground control points around the periphery of the area, a network of supplementary control is established either by graphical method or slotted template method. For this a slotted template cutter is used. It is a simple instrument and is easily available. The control obtained by these methods has been found to be very satisfactory.

B-1.8 Double Scanning Stereoscope — This is a sort of two mirror stereoscopes combined in such a way that two persons can view the same photographs from either side. It also incorporates a scanning movement which permits the operators to view the entire stereoscopic area at either of two magnifications without changing the position of the stereoscope or the photographs.

B-1.9 Miscellaneous — Other equipment needed for photo-interpretation study are drawing instruments, glass marking pencils, tracing paper, kodatrace, rapidograph, light table and good lighting conditions, cotton and spirit (methlyated).

APPENDIX C

(Clause 2.1.3)

DIFFERENT TYPES OF AERIAL PHOTOGRAPHS

C-1. Aerial photographs which are used for mapping and photo-interpretation are broadly classified into two divisions based on (1) direction of camera axis, and (2) angle of coverage.

C-1.1 Types of photographs based on direction of camera axis.

TYPE	VERTICAL	LOW OBLIQUE	HIGH OBLIQUE
i) Characteristics	Tilt less than 3°	No horizon on the photo	Horizon seen on the photo
ii) Coverage	Least	Less	Maximum
iii) Shape of area	Rectangular	Trapezoidal	Trapezoidal
iv) Scale	Uniform for one level	Decreases from foreground to background	Decreases from foreground to background
v) Difference in comparison with map	Least, looks like a map	Less	Maximum
vi) Advantages	Easiest to map	—	Economical and illustrative

C-1.2 Types of photographs based on angle of coverage.

TYPE	NARROW ANGLE	NORMAL ANGLE	WIDE ANGLE	SUPER WIDE ANGLE
i) Angle of coverage	Less than 60°	Order of 60°	Order of 90°	Order of 120°
ii) Format	—	a) 18 cm × 18 cm b) 23 cm × 23 cm	18 cm × 18 cm 23 cm × 23 cm	18 cm × 18 cm 23 cm × 23 cm
iii) Focal length	—	a) 21 cm b) 30 cm	11.5 cm 15 cm	7 cm 8 cm

APPENDIX D

(Clause 2.3.2)

NET-AREAS PER PHOTOGRAPH SIZE 23 × 23 cm
(DIFFERENT OVERLAPS SCALES)
(in km)

SCALE	ALONG FLIGHTLINE LONGITUDINAL OVERLAP	ACROSS FLIGHTLINE, LATERAL (SIDE) OVERLAP						
	60 percent	15 percent	30 percent	45 percent	30+50 percent	50 percent	60 percent	45+60 percent

km per photograph, strip inside block

15 000	1.38	2.93	2.41	1.89	2.07	1.72	1.38	1.64
20 000	1.84	3.91	3.22	2.53	2.76	2.3	1.84	2.18
25 000	2.3	4.88	4.02	3.16	3.45	2.87	2.3	2.73
30 000	2.76	5.86	4.83	3.79	4.14	3.45	2.76	3.28
40 000	3.68	7.82	6.44	5.06	5.52	4.6	3.68	4.37
50 000	4.6	9.77	8.62	6.32	6.9	5.75	4.6	5.46
60 000	5.52	11.93	9.66	7.59	8.28	8.9	5.52	6.46
100 000	9.2	19.55	16.1	12.65	13.8	11.5	9.2	10.92
120 000	11.04	23.46	19.32	15.18	16.56	13.8	11.04	13.11
125 000	11.5	24.44	20.12	15.81	17.25	14.37	11.5	13.66

km per photograph, strip along border of block

15 000	1.38	3.19	2.93	2.67	—	2.59	1.38	—
20 000	1.84	4.25	3.91	3.56	—	3.45	1.84	—
25 000	2.3	5.39	4.68	4.46	—	4.31	2.3	—
30 000	2.76	6.38	5.86	5.35	—	5.17	2.76	—
40 000	3.68	8.51	7.82	7.14	—	6.9	3.68	—
50 000	4.6	10.64	9.77	8.92	—	8.62	4.6	—
60 000	5.52	12.76	11.73	10.7	—	10.35	5.52	—
100 000	9.2	21.27	19.55	17.82	—	17.25	9.2	—
120 000	11.04	25.52	23.46	21.39	—	20.7	11.04	—
125 000	11.5	26.59	24.44	22.28	—	21.56	11.5	—

(Continued)

SCALE	ALONG FLIGHTLINE LONGITUDINAL OVERLAP	ACROSS FLIGHTLINE, LATERAL (SIDE) OVERLAP						
	60 percent	15 percent	30 percent	45 percent	30+50 percent	50 percent	60 percent	45+60 percent

Net area in km² per photo, strip inside block

15 000	4.04	3.32	2.6	2.85	2.37	1.9	2.26
20 000	7.19	8.92	4.65	5.08	4.23	3.38	4.01
25 000	11.22	9.24	7.27	7.93	6.6	5.29	6.28
30 000	16.17	13.33	10.46	11.42	9.52	7.62	9.05
40 000	28.77	23.7	18.62	20.31	16.93	13.34	16.08
50 000	44.94	37.03	29.07	31.74	26.45	21.16	25.11
60 000	65.85	53.32	41.89	45.7	38.08	30.47	36.66
100 000	179.86	148.12	116.38	116.38	105.8	84.64	100.46
120 000	259.00	213.29	167.58	167.58	152.35	121.88	144.73
125 000	281.06	231.38	181.81	181.81	165.25	132.25	157.09

Net area in km² per photo, strip along border of block

15 000	4.4	4.04	3.69	—	3.57	1.9	—
20 000	7.82	7.79	6.55	—	6.35	3.38	—
25 000	12.4	11.22	10.26	—	9.91	5.29	—
30 000	17.6	16.17	14.76	—	14.27	7.62	—
40 000	31.31	28.77	26.27	—	25.39	13.54	—
50 000	48.94	44.94	41.03	—	39.65	21.16	—
60 000	70.43	64.75	59.06	—	57.13	30.47	—
100 000	195.68	179.86	163.94	—	158.7	84.64	—
120 000	281.85	259.00	236.14	—	228.53	121.88	—
125 000	305.78	281.06	256.22	—	247.94	132.25	—

APPENDIX E*(Clause 2.4)***RECOMMENDED SCALES OF AERIAL PHOTOGRAPHS FOR INVESTIGATIONS OF RIVER VALLEY PROJECTS**

SCALE OF AERIAL PHOTOGRAPHS	TYPE OF INVESTIGATION
1 : 50 000 to 1 : 60 000	i) Preliminary investigations for reservoir area. ii) Geological studies for catchment area, silt control and collection of hydro-meteorological data. iii) Reconnaissance survey for tunnel alignment. iv) Reconnaissance survey for command area.
1 : 25 000 to 1 : 30 000	i) Preliminary investigations for dam and power house site. ii) Detailed investigations of reservoir area. iii) Detailed investigations for tunnel alignments. iv) Preliminary survey for canal construction. v) Study of earthquake effects.
1 : 10 000 to 1 : 15 000	i) Soils studies for catchment area, silt control and collection of hydro-meteorological data. ii) Detailed survey for canal construction. iii) Detailed mapping of command area.
1 : 5 000	Detailed investigations of dam and power house site.

APPENDIX F*(Clause 2.4)***SUGGESTED SUITABLE SCALES OF AERIAL PHOTOGRAPHS AND MAPS FOR GEOLOGICAL MAPPING****F-1. AERIAL PHOTOGRAPHS****F-1.1 Detailed Mapping****Photo Scale**

- | | |
|---|---|
| i) Desert country and arid areas of low relief | 1 : 15 000 to 1 : 25 000 |
| ii) For arid country with moderate to high relief | 1 : 25 000 to 1 : 50 000
the larger scale to be obtained by longer focal length, flown at a higher level |

- | | |
|---|--------------------------|
| iii) For low, open jungle country with low to moderate relief | 1 : 25 000 to 1 : 40 000 |
| iv) For tall jungle country with low to moderate relief | 1 : 40 000 to 1 : 50 000 |
| v) For tall jungle country with high relief | 1 : 50 000 |

F-1.2 For Reconnaissance Mapping and General Correlation

Photo Scale

- | | |
|---|--|
| i) Open country with low or moderate relief | 1 : 30 000 to 1 : 40 000 |
| ii) Open country with high relief | 1 : 50 000 to 1 : 60 000 |
| iii) Thickly forested country with any type of relief | 1 : 50 000 |
| iv) Any type of country | 1 : 100 000 to 1 : 120 000
with first class photography |

F-2. MAPS

F-2.1 Type of Study

Map-Scale

F-2.1.1 Regional Studies

1 : 50 000 with contour intervals of 10 to 20m to 1 : 250 000 with contour intervals of 50 to 100 m

F-2.1.2 Detailed Study

1 : 5 000 with contour intervals of 1 to 5 m to 1 : 25 000 with contour intervals of 5 to 20 m

APPENDIX G

(Clause 4.2)

SEQUENCE OF OPERATIONS

G-1. Sequence of various operations in production of photo-geological maps, if all are carried out by one and the same operator.

-
- A. 1. Laying out loose mosaic and checking overlaps
 2. Perusal of whole area under stereoscope and preliminary notes on geology, morphology, etc
 3. Marking approximate centre of overlap between strips
 4. Transferring principal points and inking them in
-
- B. 5. Choosing tie and wingpoints (marking their approximate position)
 6. Sketching flight-plan and triangular network
 7. Transferring tie and wingpoints
 8. Inking in these
-
- C. 9. Choosing and transferring ground control points
 10. Calculating scale of photographs and average scale of map
 11. Calculating coordinates of ground control points
 12. Plotting ground control points on base map
-
- D. 13. Drawing base lines and rays
 14. Arundel plot proper
 15. Reduction or/and enlargement of strips
 16. Finishing off base map
 17. Bringing base map to scale of photos
- } Arundel only
 (Optional)
-
- E. 18. Cutting templates to shape
 19. Transferring points to templates
 20. Cutting slots
 21. Assembling templates
 22. Finishing off base map
 23. Bringing base map to scale of photos
- } Slotted template only
 (Optional)
-
- F. 24. Choice and transfer of auxiliary points
 25. Intersecting these on base map
- } (Optional)
-
- G. 26. Working out photos (interpretation, annotation)
-

- H. 27. Transferring annotation to base map
 - a) Direct transfer by gradual shifting
 - b) Transfer by sketchmaster
 - c) Transfer by radial line plotter
 - d) Transfer by projector rectifier
 - e) Direct mapping by stereotop or stereopret
-
- I. 28. Tracing of completed map including lettering, legend, etc
 - 29. Colouring print
-
- J. 30. Planning field work for ground checking the photo-interpretation (can mostly be done at earlier stage, for example, A above)
-